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(54) Reflection-type multi-color liquid crystal display device

(57) A reflection-type multi-color liquid crystal display device is fabricated by superposing a first substrate 27, reflecting electrodes 25, color filter layers 26, a transparent second substrate 22 and a polarizing plate 21, and then filling a liquid crystal 24 between the first and second substrates. The second substrate carries tranparent electrodes on one side thereof, which one side faces the first substrate. The reflecting electrodes replace the external reflection used in the prior art and have the effect of minimizing the parallactic angle and improving the image quality.

FIG. 2(a)

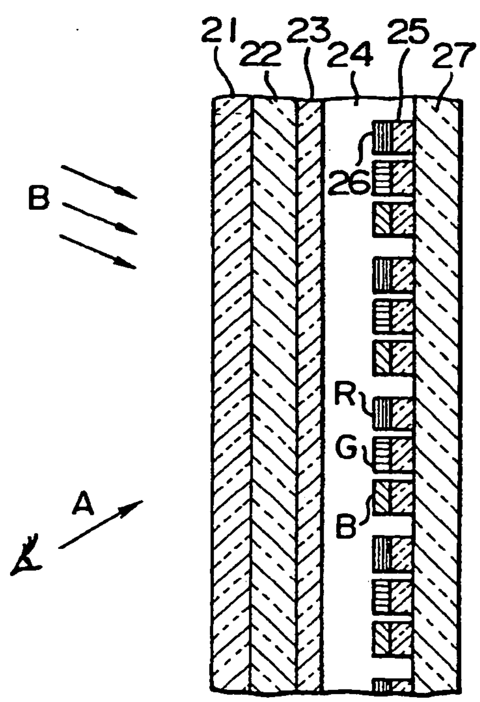

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FIG.1

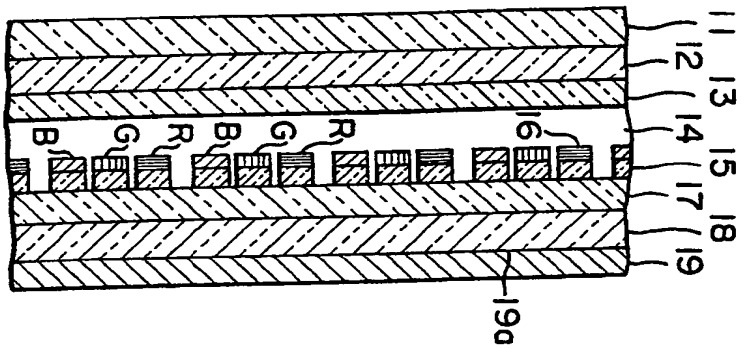
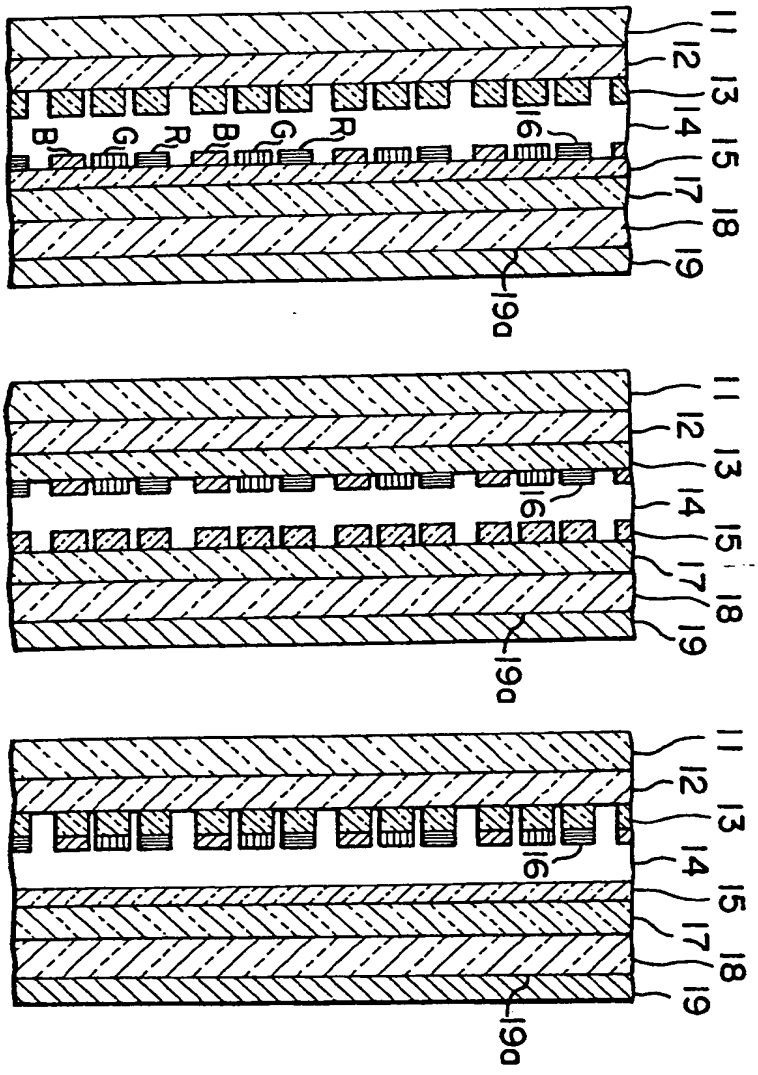


FIG.3



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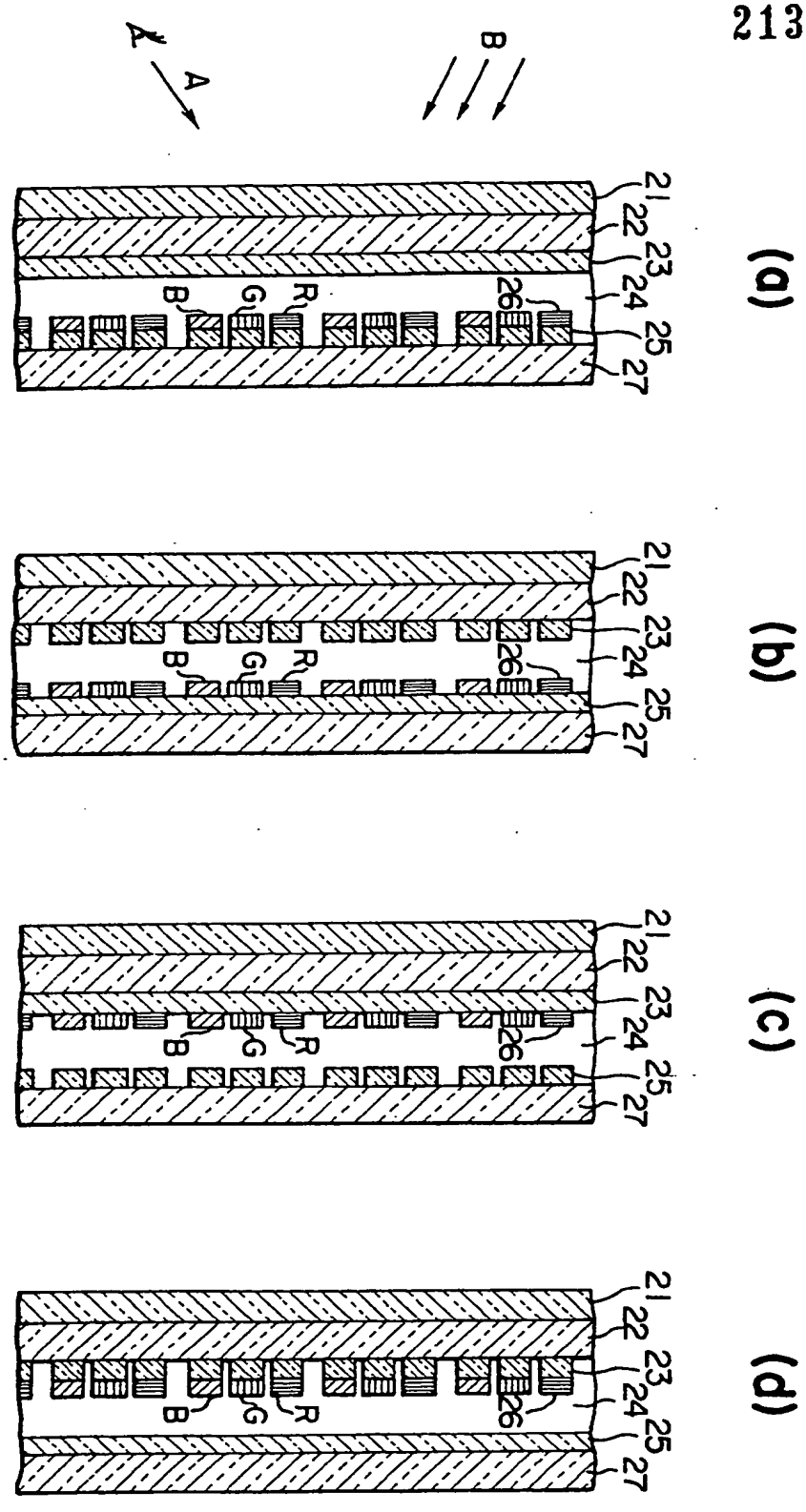

FIG. 2

SPECIFICATION

Reflection-type multi-color liquid crystal display device

This invention relates to a liquid crystal display device, and more particularly to a reflection-type multi-color liquid crystal display device which makes use of a guest-host type liquid crystal material.

Multi-color image display devices which rely upon liquid crystal materials have found commercial utility in terminal display units of computers, television sets, video monitors, etc. A great deal of research and development work has, in recent years, been made on such multi-color image display devices.

A fabrication method of such a multi-color image display unit is disclosed, for example; in japanese patent Laid-open No. 58-102214 filed by the present assignee, which is hereby incorporated herein by reference.

It is however indispensable to provide a light source behind a multi-color image display device where the display device is fabricated as a transmission-type display device by using two polarizing plates. In view of the fact that the great feature of a liquid crystal display device resides in a small power consumption, it is not preferred to incorporate a light source additionally.

In order to make the luminace brightness of a display device uniform, it is necessary to superpose a diffusing plate such as frosted glass right behind the display device so that each incident light is scattered well.

In a reflection-type display unit including a reflecting plate arranged closely outside one of the polarizing plates, multi-color display is achieved by means of fine color filter layers. Accordingly, the display characteristics are heavily dependent on visual angles. Therefore, such a reflection-type display unit is accompanied by a drawback that display picture elements would be reduced in contrast at certain visual angles.

Reflection-type display devices which do not require light sources are favorably employed as blackand-white display devices in desk-top calculators, watches, etc. However, there has not been known any display device which is capable of displaying desired patterns in desired colors.

It may be contemplated to form a color filter layer, the pattern of which corresponds to an internal electrode arrangement of a liquid crystal display device, on the outer surface of a glass substrate which makes up the display device. However, the thickness of the glass substrate will become hardly ignorable especially when the picture elements of the display device are fine, thereby developing a parallactic angle and hence producing a color difference depending on the position of each viewer. It is thus impossible to obtain good image quality.

With the foregoing in view, the principal object of this invention is to provide, without need for any separate light source, a reflection-type multi-color liquid crystal display device which can display desired patterns and images.

This invention provides a reflection-type multi-colour liqiud crystal displat device comprising:

a transparent or opaque first substrate;

reflecting electrodes formed on one side of the first substrate;

color filter layers formed corresponding respectively to predetermined portions of the reflecting electrodes;

a transparent second substrate provided in opposition to the first electrode with a predetermined interval therebetween and carrying transparent electrode on one side thereof, which one side faces the first substrate; and

a polarizing plate;

said first substrate, reflecting electrodes, color filter layers, second substrate and polarizing plate having been superposed one over another in the same order as they have been recited above; and

a liquid crystal material filled between the first and second substrates.

The color filter layers may be provided over at least either one of the reflecting electrodes or transparent electrodes.

The reflection-type multi-color liquid crystal display device of this invention requires neither light source nor special structure adapted to favorably scatter light from the light source, permits to save power consumption and features simpler handling upon its application.

Furthermore, the parallectic angle can be minimized and extremely good image quality can thus be obtained since the color filter layers are provided directly over the electrodes.

The above and other objects, features and advantages of the present invention will become apparent from the following description and the appended claims, taken in conjunction with the accompanying drawings, in which:

Fig. 1 is a fragmentary, longitudinal, cross-sectional view of a conventional reflection-type multi-color liquid crystal display device which makes use of a twisted nematic liquid crystal material;

Figs. 2(a) through 2(d) are fragmentary, longitudinal, cross-sectional views of reflection-type multi-color liquid crystal display devices, each of which makes use of a guest-host type liquid crystal material and pertains to the present invention; and

Figs. 3(a) through 3(c) are fragmentary, longitudinal, cross-sectional views of reflection-type multi-color liquid crystal display devices, each of which has been fabricated by applying a little modification to the prior art

example of Fig. 1 and pertains to the present invention.

Reference is first of all made to Fig. 1 which illustrates a reflection-type multi-color liquid crystal display device making use of a TN (twisted nematic) liquid crystal material.

As it is of the reflection-type, a line A of sight and incident light *B* are both located at the same side of the device. In the illustrated example, a TN-type liquid crystal material 14 is hermetically filled between two sheets of glass substrates 12, 17. On the mutually-opposing surfaces of the glass substrates 12, 17, transparent electrodes 13, 15 are respectively formed with In_2O_3 or the like into comb-like shapes in such a way that the transparent electrodes 13 extend at right angles with the transparent electrodes 15, thereby to form a single unit of matrix.

In the case of the example depicted in Fig. 1, color filter layers 16 of R-, G- and B-colors are applied over the front surface of the transparent electrodes 15 which are located in rear portions as seen along the line *A* of sight.

The layers superposed respectively on the outer surfaces of the glass substrates 12, 17 are polarizing plates 11, 18. The axes of polarization of these polarizing plates 11, 18 are parallel to each other. The polarizing plates 11, 18 may however be disposed in such a way that their axes of polarization cross at right angle. In the latter case, there is obtained a negative image relative to the image available in the former case.

The above-described display device has the same structure as transmission-type multi-color liquid crystal devices. It may be fabricated, for example, in accordance with the fabrication method disclosed in the above-referred to Japanese Patent Laid-open No.58-102214 In the above example, a reflecting plate 19 is provided at the very behind of the structure. The reflecting plate 19 may for example be formed by adhering a film or the like carrying a metal such as Al, Cr, Ag or the like deposited thereon over the outer surface of the polarizing plate 18 with its reflecting surface 19a facing toward the liquid crystal material.

Certain preferred embodiments of this invention will hereinafter be described with reference to Figs. 2(a) through 3(c).

Figs. 2(a) through 2(d)illustrate embodiments, each of which makes use of a guest-host type liquid crystal material.

Incidentally, the term "guest-host type liquid crystal material" as used herein means a liquid crystal material in which a dichromatic pigment having a desired color is mixed in the liquid crystal material and the orientation of the pigment is changed together with the orientation of molecules of the liquid crystal material upon application of an electric field thereto.

As illustrated in each of Figs.2(a) through 2(d), a liquid crystal 24 is hermetically filled between two sheets of glass substrates 22, 27. On the mutually-opposing surfaces of the glass substrates 22, 27, there are respectively formed transparent electrodes 23 made of In_2O_3 or the like and reflecting electrodes 25 made of Al, Cr, Ag or the like. The electrodes 23, 25 are repsectively formed into comb-like shapes and extend at right angle in opposition to each other, whereby forming a single unit of matrix.

In each of the embodiments illustrated respectively in Figs. 2(a) and 2(b), color filter layers 26 of R-, G- and B-colors are applied over the front surfaces of reflecting electrodes 25 which are arranged at rear portions. The frontmost layer is a polarizing layer 21.

In the embodiments of Figs. 2(a) and 2(b), it is not necessary that a glass substrate 27 be transparent. On the contrary, it is preferred that the glass substrates 27 can shield light so as to prevent external light from entering through the rear wall.

A guest-host type liquid crystal is also used in each of the embodiments depicted respectively in Figs. 2(c) and 2(d). The liquid crystal 24 is hermetically filled between two sheets of glass plates 22, 27. Transparent electrodes 23 and reflecting electrodes 25 are respectively formed on the mutually-opposing surfaces of the glass substrates 22, 27. Numeral 21 indicates a polarizing plate.

In the embodiment of Fig.s 2(c) and 2(d), the color filter layers 26 are provided on the rear surfaces of the transparent electrodes 23.

In the case of the emobidments of Figs. 2(c) and 2(d), the transmission path of light for displaying images is shorter by the thickness of the layer of the liquid crystal material, which is located between the transparent electrodes 23 and the reflecting electrodes 25, compared with the embodiments of Figs. 2(a) and 2(b). Therefore, the embodiments of Figs. 2(c) and 2(d) can provide good image quality having a still smaller parallactic angle.

Figs. 3(a) through 3(c) illustrate reflection-type multi-color liquid crystal display devices which have been fabricated by applying the present invention to the conventional example of Fig. 1 in various ways.

In the conventional example of Fig. 1, the color filter layers 16 and electrodes 15 are formed at the right-hand-side.

In Fig. 3(a), color filter layers 16 are formed, similar to the embodiment of Fig. 2(b), at the right-hand side as seen in the drawing, whereas electrodes 13 adapted to choose the color filter layers 16 are formed at the left-hand side as seen in the drawing. In Fig. 3(b), color filter layers 16 are formed similar to the embodiment of Fig. 2(c), at the left-hand side as seen in the drawing, while electrodes 15 which serve to select the color filter layers 16 are formed at the right-hand side as seen in the same drawing. In Fig. 3(c), color filter layers 16 and electrodes 13, which

are adapted to choose the color filter layers 16, are both formed at the left-hand side as seen in the drawing.

In the above-given description of the above embodiments, there is no reference to the specific manner of driving the matrix electrodes. Needless to say, they may be driven in various ways, for example, in accordance with the time-divided driving method, the driving method relying upon a thin-film transistor, or the like.

Especially, in the case of the driving method relying upon a thin-film transistor, it is feasible to form the rear glass substrate by the SOS (silicon-onsapphire) substrate of the thin-film transistor and the reflecting electrodes by silicon chips *per se*.

Having now fully described the invention, it will be apparent to one of ordinary skill in the art that many changes and modifications can be made thereto without departing from the spirit or scope of the invention as set forth herein.

CLAIMS

1. A reflection-type multi-color liquid crystal display device comprising:

a transparent or opaque first substrate;

refelcting electrodes formed on one side of the first substrate;

color filter layers formed corresponding respectively to predetermined portions of the reflecting electrodes;

a transparent second substrate provided in opposition to the first electrode with a predetermined interval therebetween and carrying transparent electrodes on one side thereof, which one side faces the first substrate; and

a polarizing plate;

said first subtrate, reflecting electrodes, color filter layers, second substrate and polarizing plate having been superposed one over another in the same order as they have been recited above; and

a liquid crystal material filled between the first and second substrates.

2. A reflection-type multi-color liquid crystal display device as claimed in Claim 1, wherein the color filter layers are formed over the surfaces of their corresponding reflecting electrodes.

3. A reflection-type multi-color liquid crystal display device as claimed in Claim 1, wherein the color filter layers are formed over the surfaces of the transparent electrodes.

4. A reflection-type multicolour liquid crystal device substantially as hereinafter described with reference to and as illustrated in the accompanying drawings.

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